



MISSE Thermal Control Materials

With Comparison to Previous Flight Experiments

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Materials on International Space Station Experiment (MISSE)

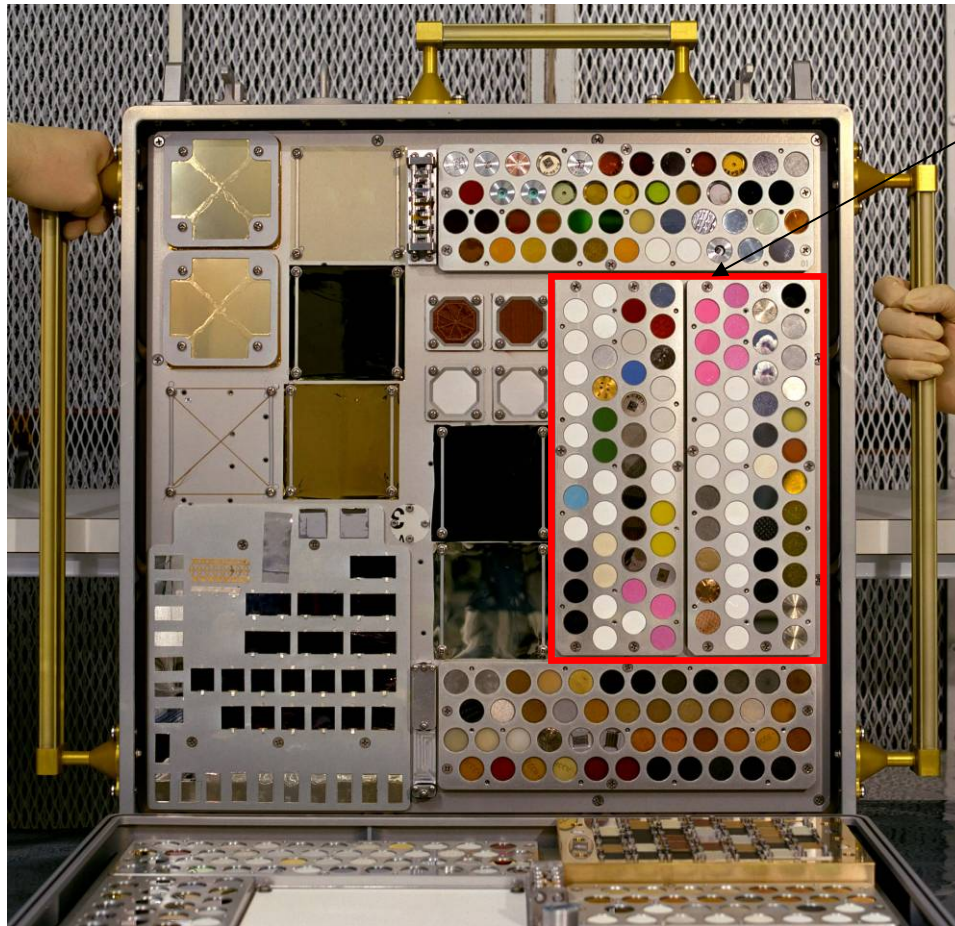
Over 4,000 material samples exposed to the space environment with 5 MISSE “suitcases” from August 2001 to August 2007

Effects of Atomic Oxygen, Ultraviolet Radiation, Thermal Cycling, Vacuum on:

- Zinc oxide / potassium silicate thermal control coating
 - Z-93/Z-93P from Alion Science (formerly IITRI)
 - AZ93 from AZ Technology
- Deft polyurethane coatings
- Lord Chemical A-276 with leafing aluminum

NASA gives no recommendation, endorsement, or preference, either expressed or implied, concerning vendors of the materials discussed in this paper.

MISSE Thermal Control Materials With Comparison to Previous Flight Experiments



Trays E2, E3
Located on ram-facing
side of MISSE-1

9.45×10^{21} atoms/cm²
calculated AO fluence

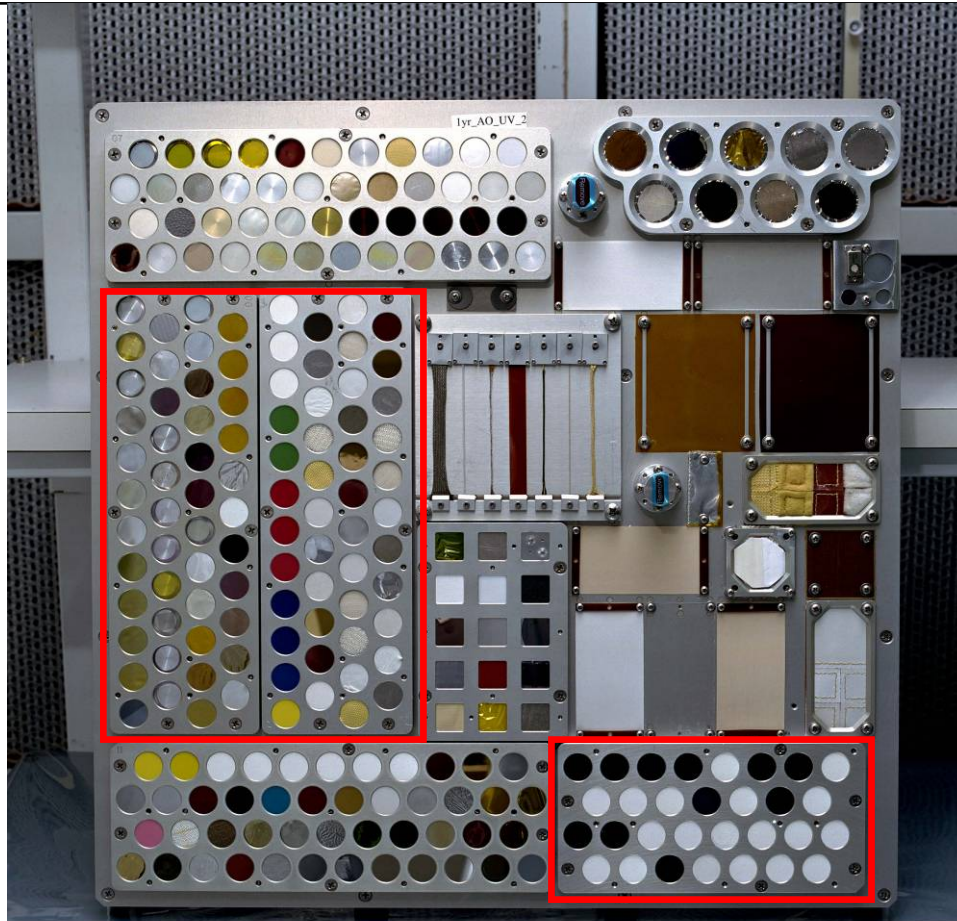
5,545 – 6,152 ESH
calculated solar exposure

MISSE 1
Materials International Space Station Experiment
AO/UV tray
PEC 1, Tray 1

“Estimated Environmental Exposures for MISSE-1 & MISSE-2”
Dr. Gary Pippin and Dr. Eugene Normand
Boeing Phantom Works

Photo courtesy of Langley Research Center

MISSE Thermal Control Materials With Comparison to Previous Flight Experiments



MISSE 2
Materials International Space Station Experiment
AO_UV_1 tray (PEC 2, tray 1)

Trays D1, E7, E8
Located on ram-facing side
of MISSE-2

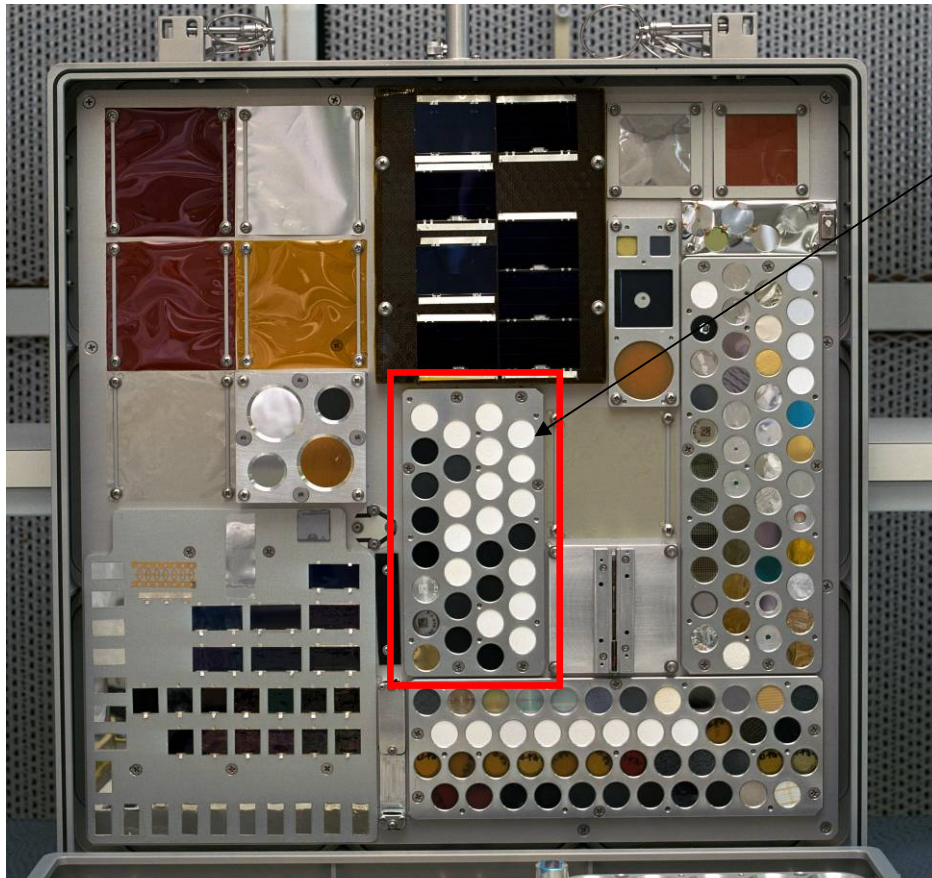
7.2 to 7.6×10^{21} atoms/cm²
measured AO fluence
(mass loss of surviving
polymers)

5,100 – 6,000 ESH
calculated solar exposure

Photo courtesy of Langley Research Center

“Estimated Environmental Exposures for MISSE-1 & MISSE-2”
Dr. Gary Pippin and Dr. Eugene Normand
Boeing Phantom Works

**MISSE Thermal Control Materials
With Comparison to Previous Flight Experiments**



Tray D2
On nominally wake-
facing side of MISSE-2

1.4×10^{20} atoms/cm² by
thickness loss of polymer
samples

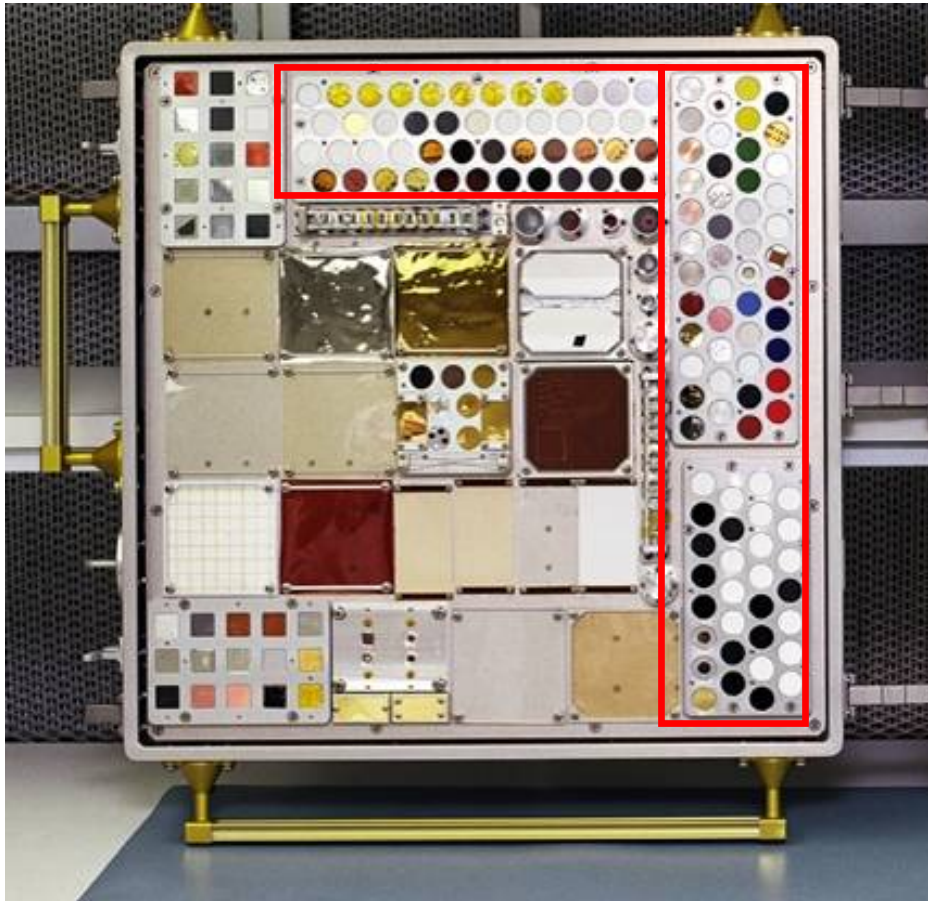
4,760 – 5,130 ESH
calculated solar exposure

MISSE 2
Materials International Space Station Experiment
UV_2 tray (PEC 2, tray 2)
Full Tray

“Estimated Environmental Exposures for MISSE-1 & MISSE-2”
Dr. Gary Pippin and Dr. Eugene Normand
Boeing Phantom Works

Photo courtesy of Langley Research Center

**MISSE Thermal Control Materials
With Comparison to Previous Flight Experiments**

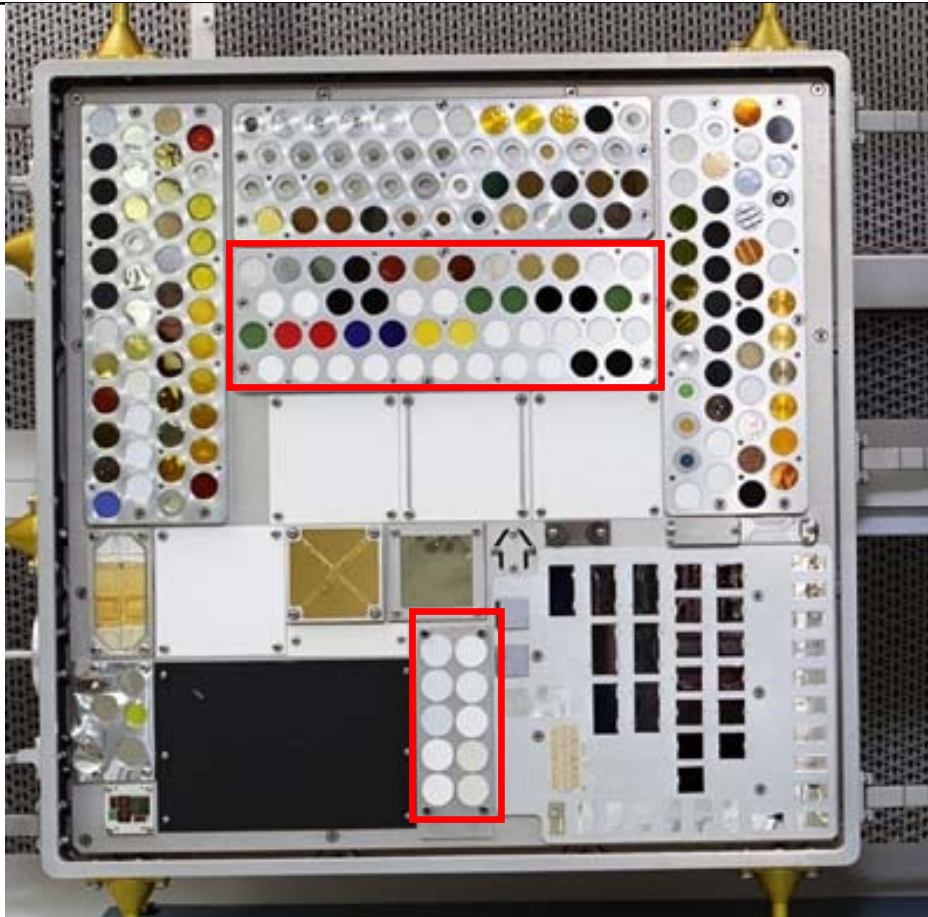


Trays D4, E13, E14
On nominally ram-facing
side of MISSE-3

1.3×10^{21} atoms/cm² by
mass and thickness loss of
polymer samples

~1,500 ESH
calculated solar exposure

**MISSE Thermal Control Materials
With Comparison to Previous Flight Experiments**

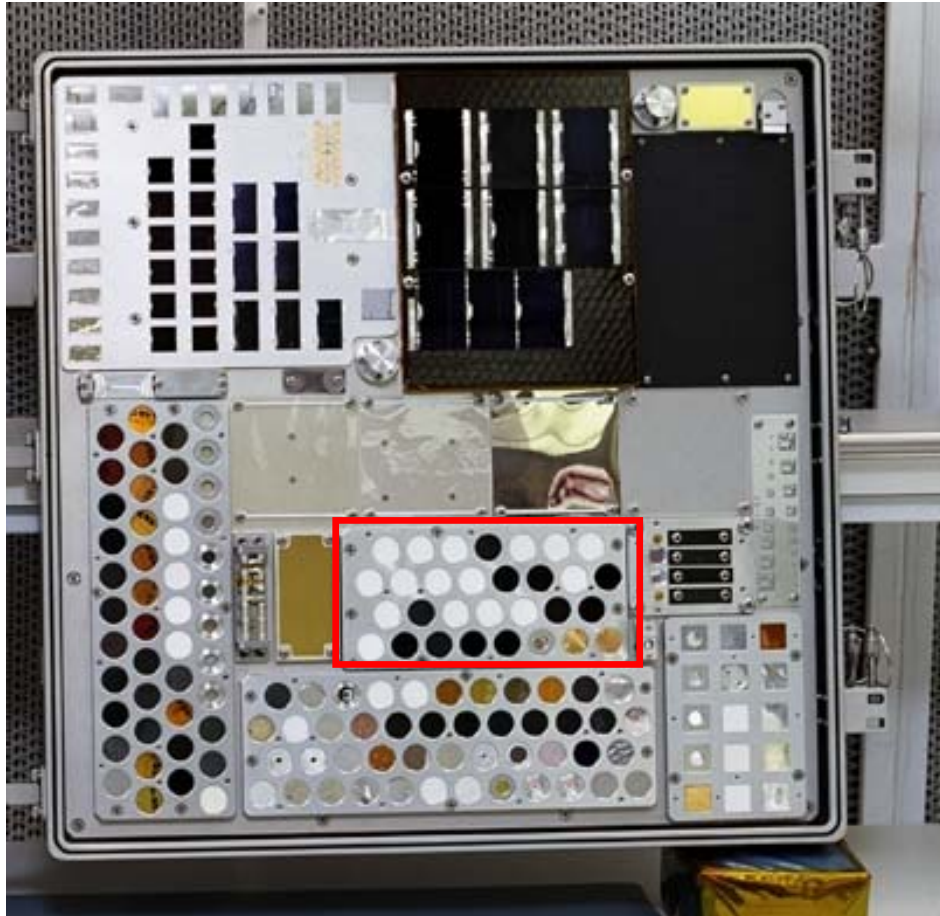


Trays B23, E17
On nominally ram-facing
side of MISSE-4

1.8×10^{21} atoms/cm² by
mass and thickness loss of
polymer samples

~1,200 ESH
approximate solar
exposure

**MISSE Thermal Control Materials
With Comparison to Previous Flight Experiments**



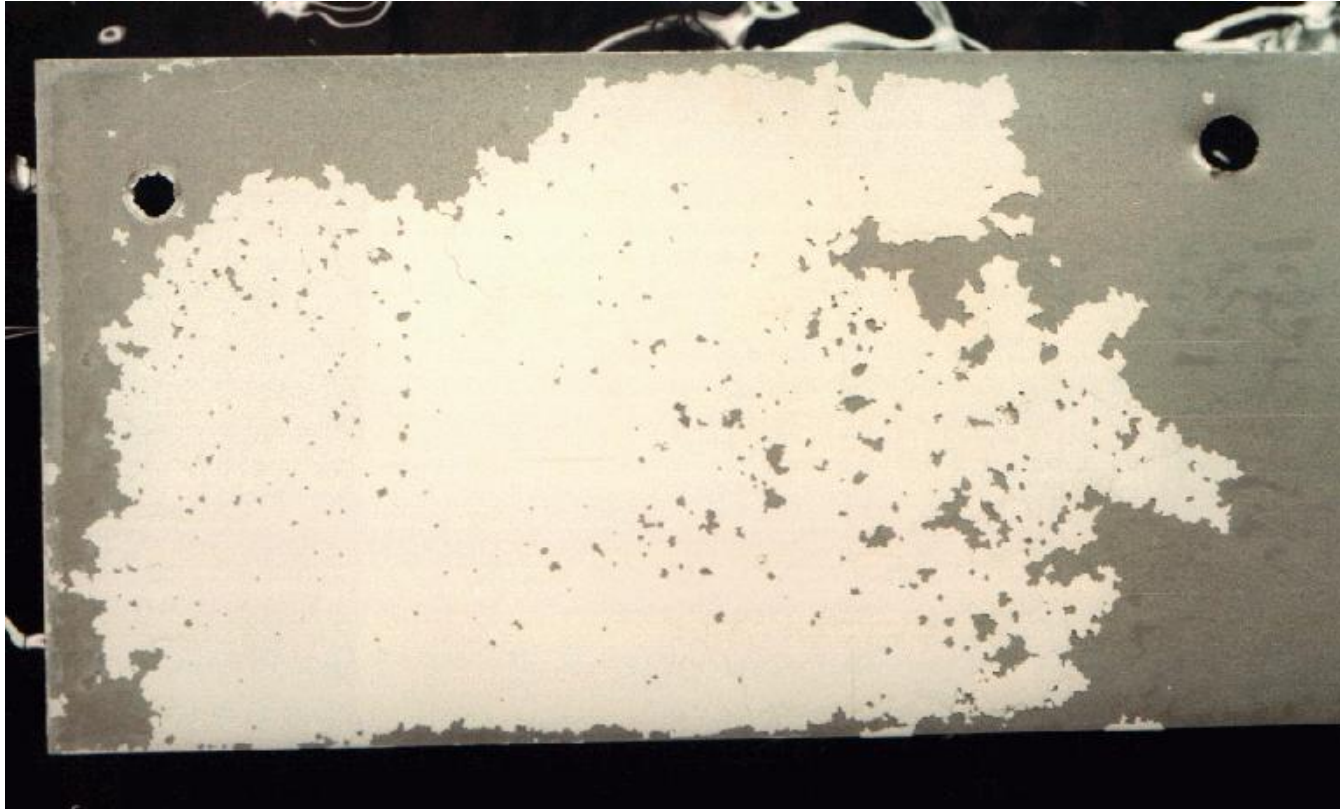
Tray D6

On nominally wake-
facing side of MISSE-4

2.0×10^{20} atoms/cm² by
modeling

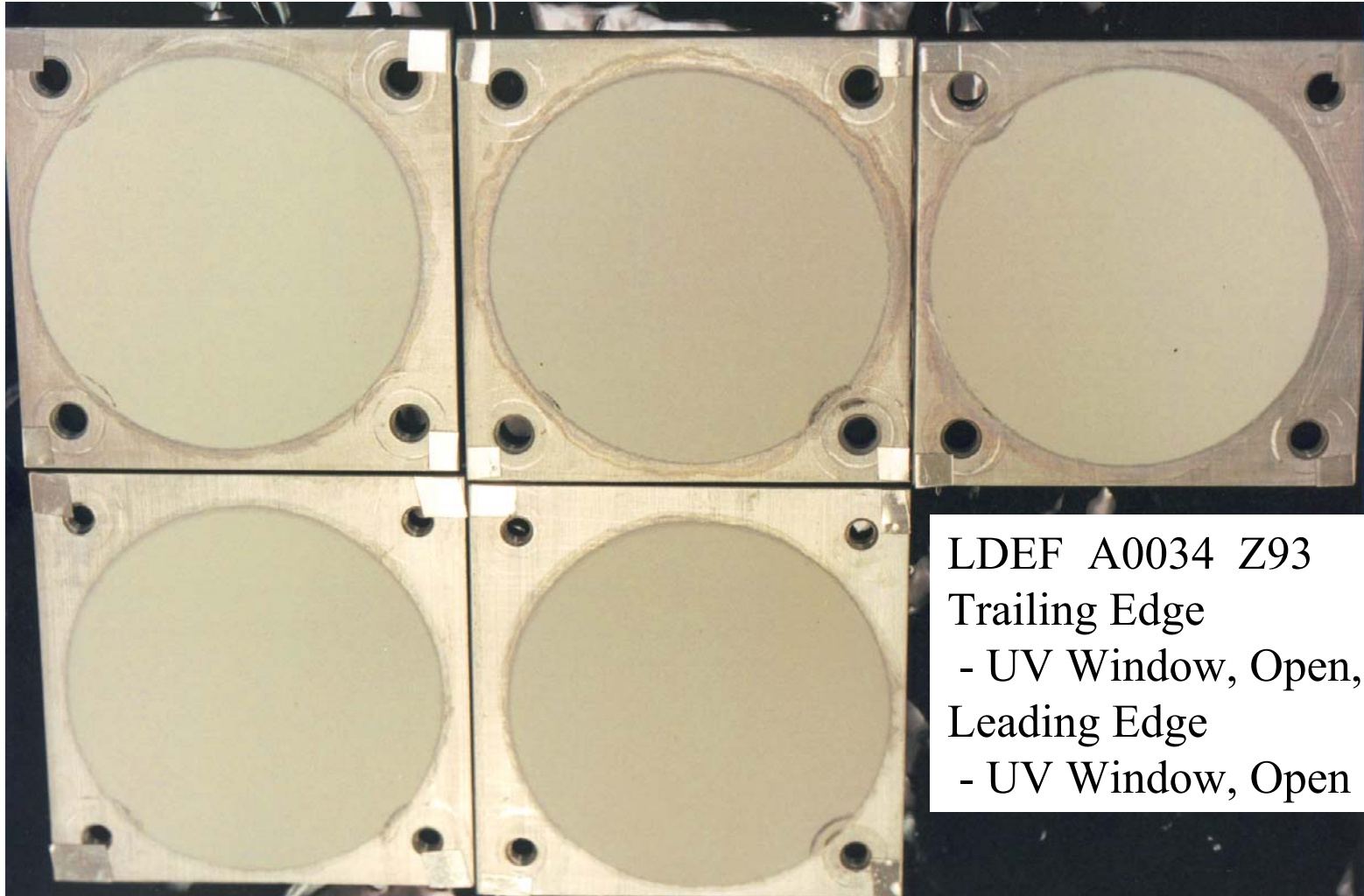
~1,200 ESH
approximate solar
exposure

MISSE Thermal Control Materials
With Comparison to Previous Flight Experiments



Z-93P / AZ93 has good durability in the space environment
IF applied properly and molecular contamination is minimized.

**MISSE Thermal Control Materials
With Comparison to Previous Flight Experiments**



LDEF A0034 Z93

Trailing Edge

- UV Window, Open, Covered

Leading Edge

- UV Window, Open

**MISSE Thermal Control Materials
With Comparison to Previous Flight Experiments**



POSA-I Control

Space-facing $\sim 5,000\text{\AA}$ SiO_x

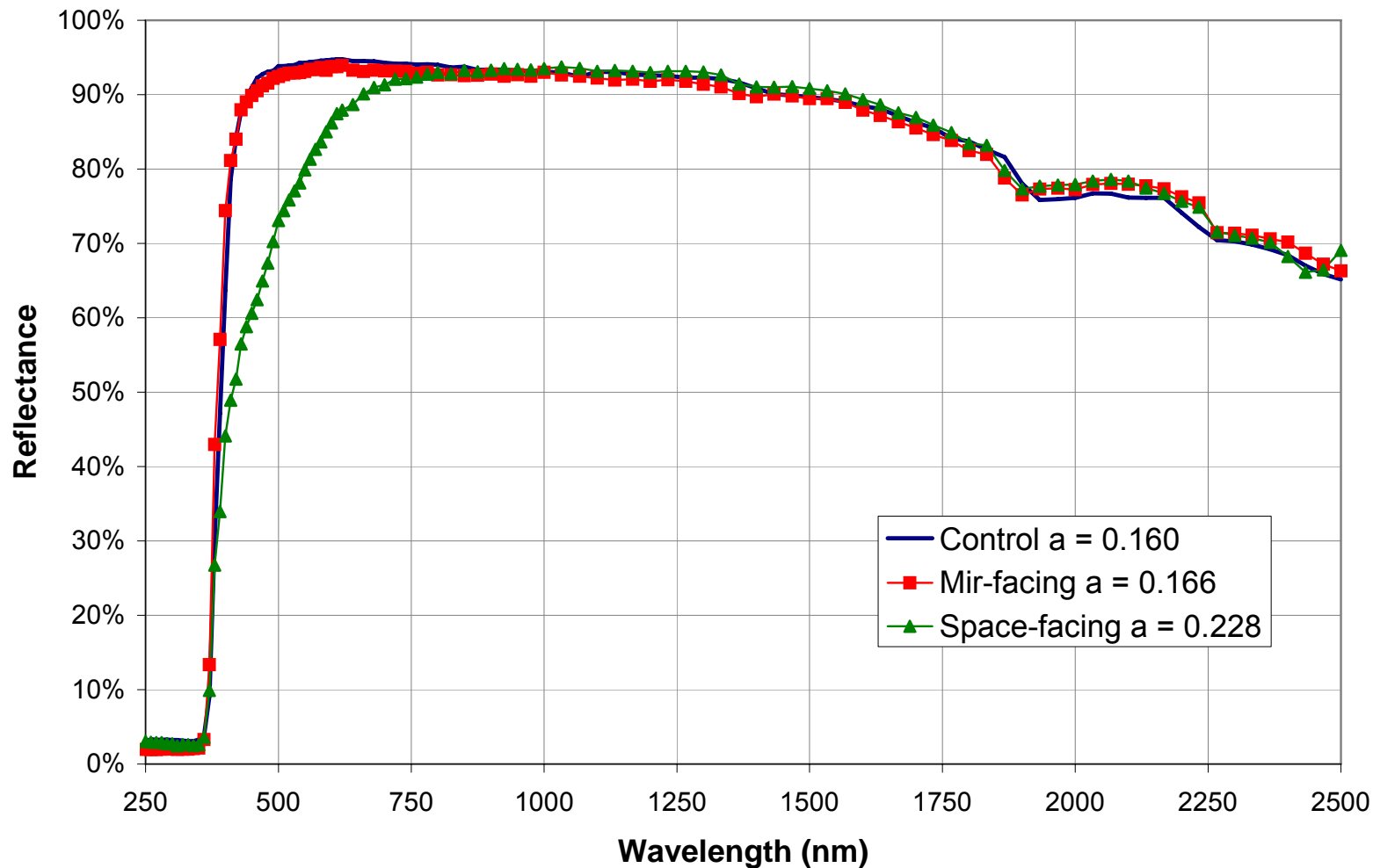
Mir-facing $\sim 250\text{\AA}$ SiO_x

MISSE Thermal Control Materials
With Comparison to Previous Flight Experiments



POSA-I Z-93P

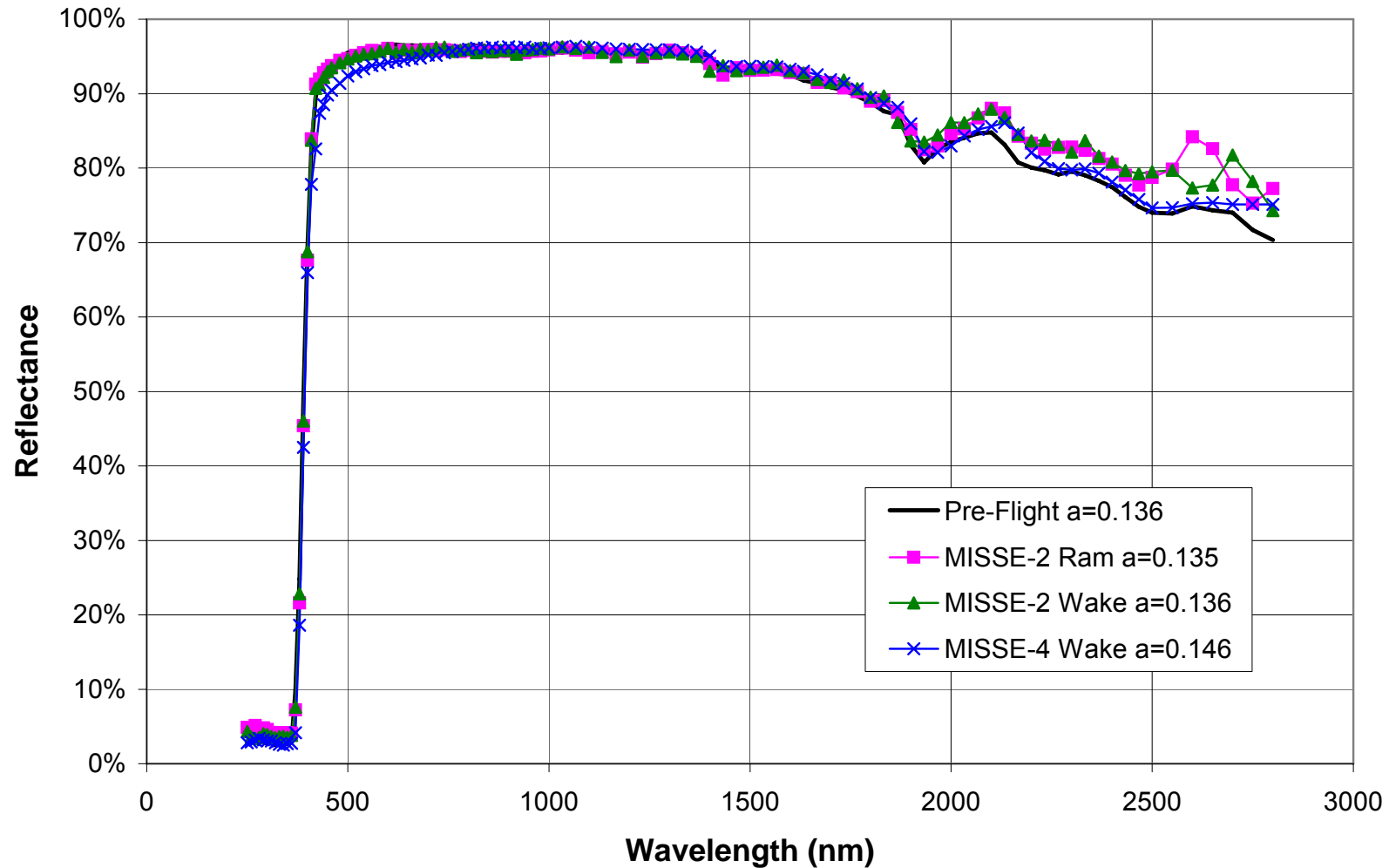
After 18 months on *Mir*



MISSE Thermal Control Materials With Comparison to Previous Flight Experiments



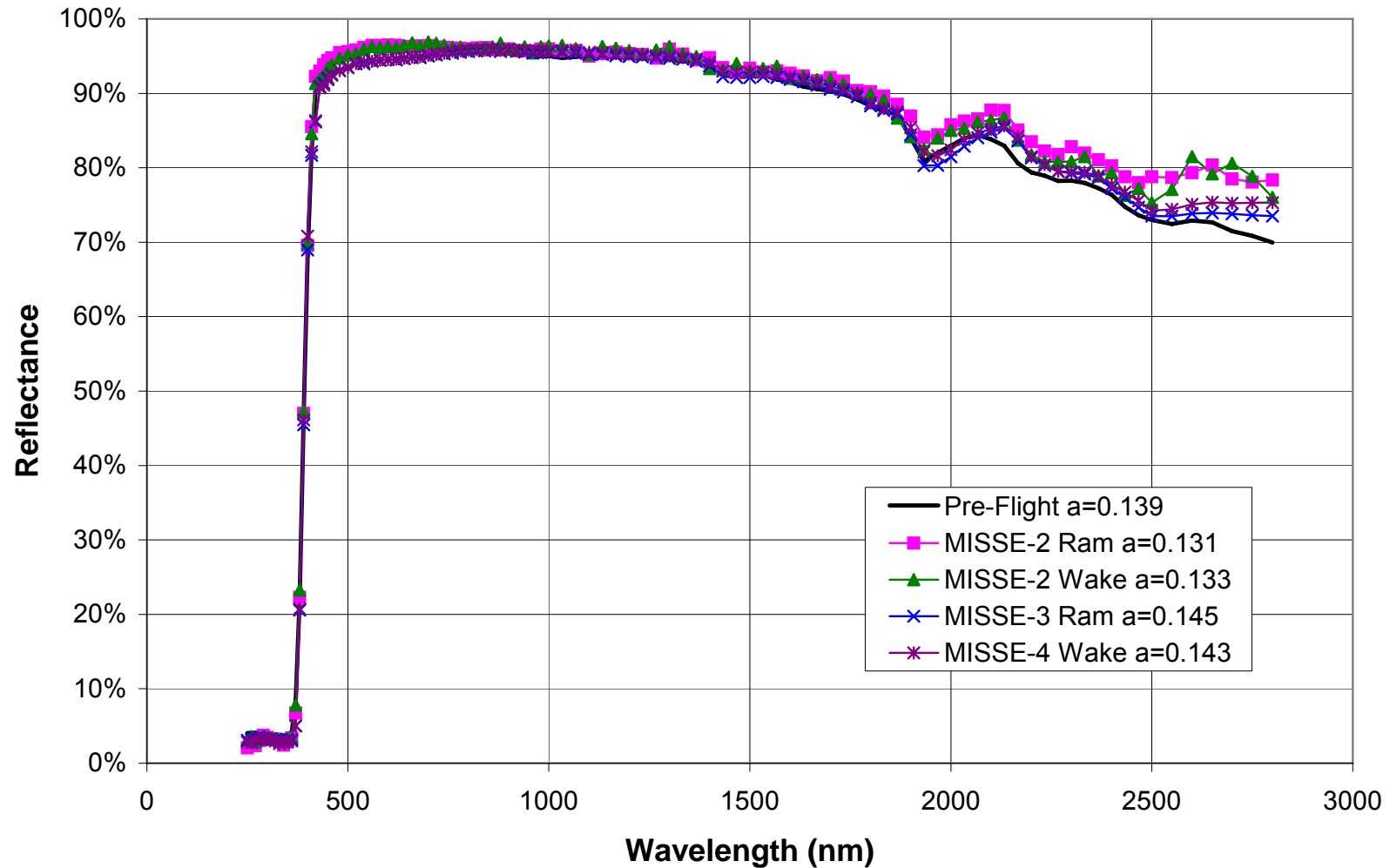
Z93 - Original Binder



MISSE Thermal Control Materials With Comparison to Previous Flight Experiments



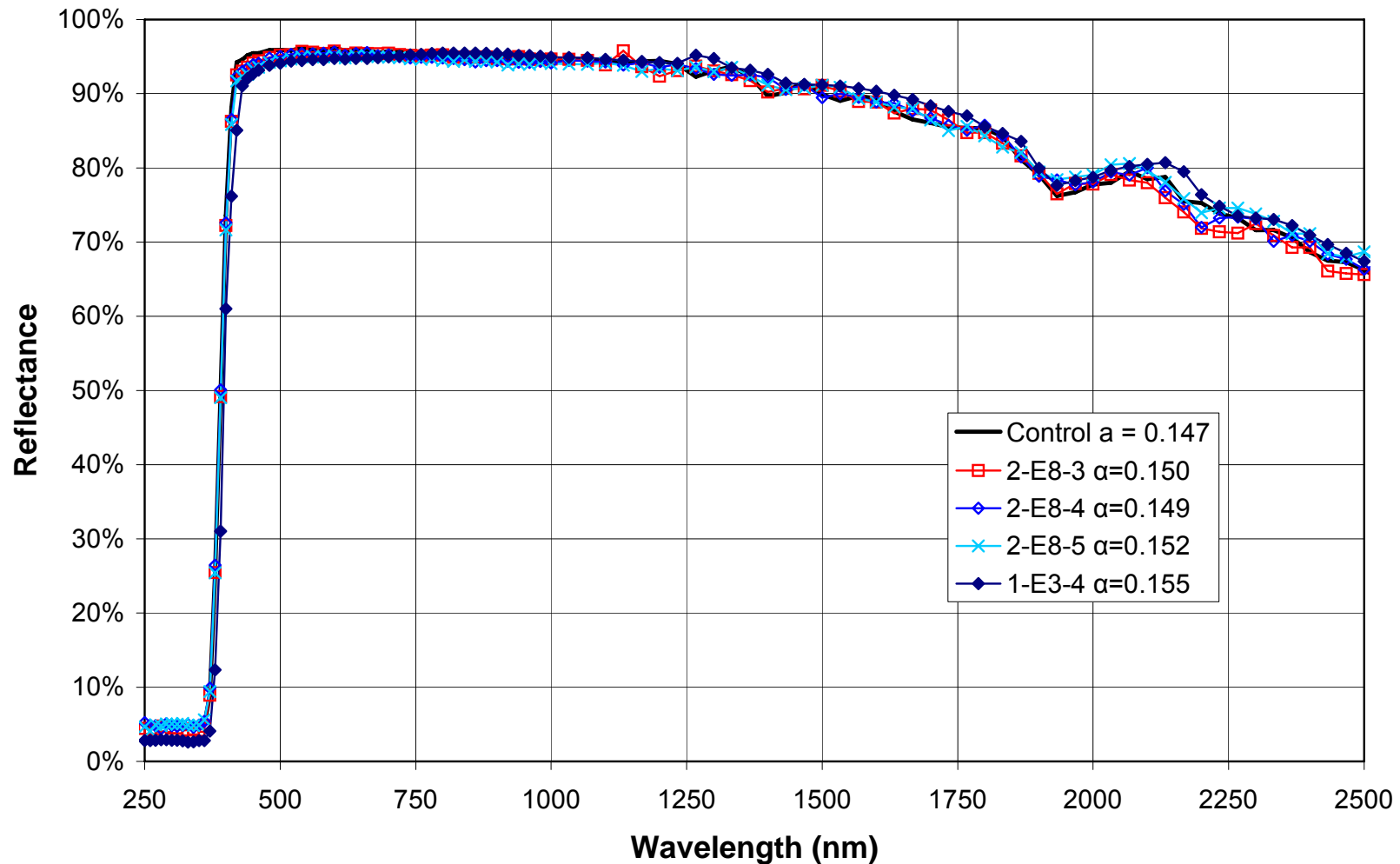
Z93P



MISSE Thermal Control Materials
With Comparison to Previous Flight Experiments



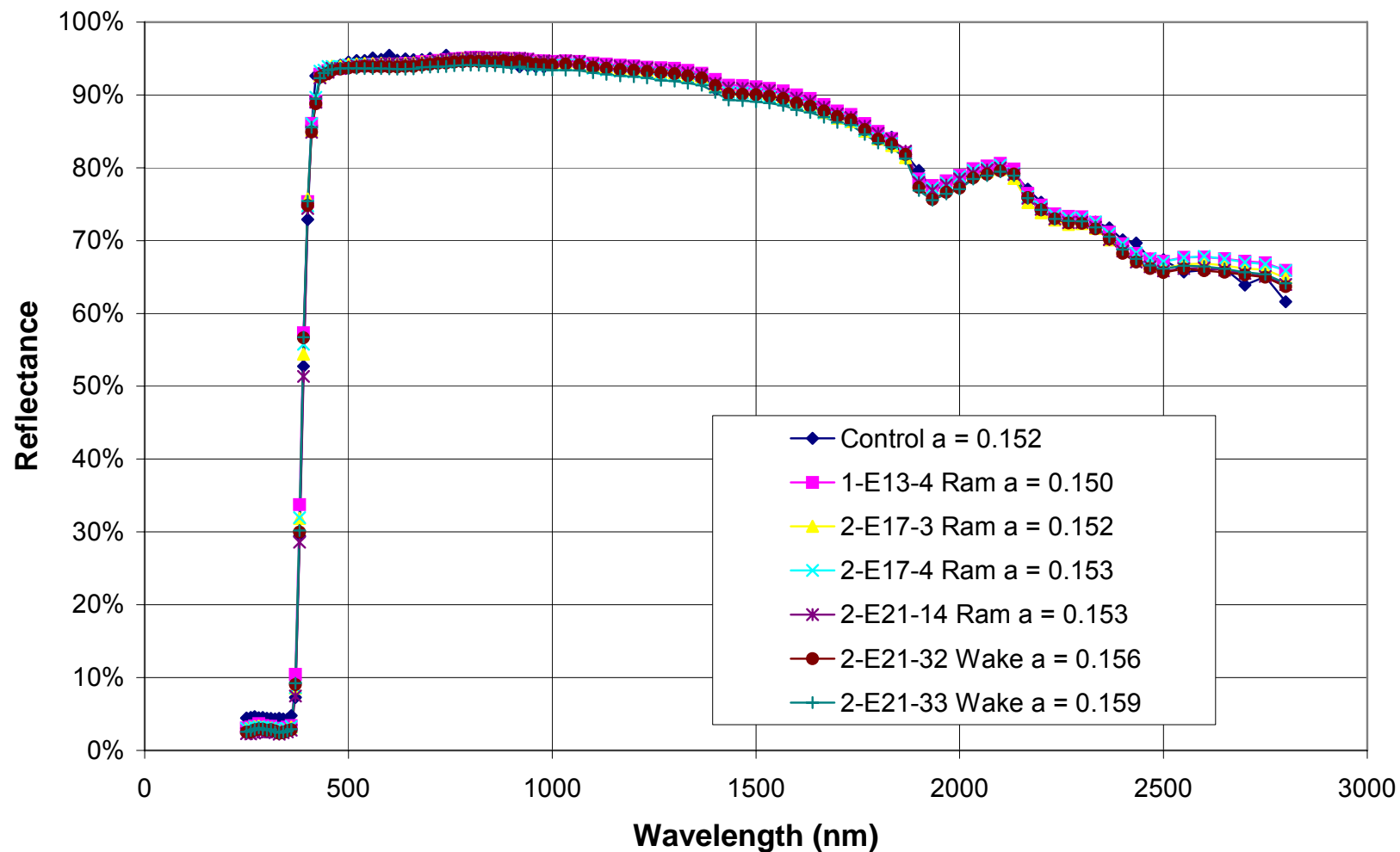
MISSE-2 AZ93 Inorganic White Coating



MISSE Thermal Control Materials
With Comparison to Previous Flight Experiments



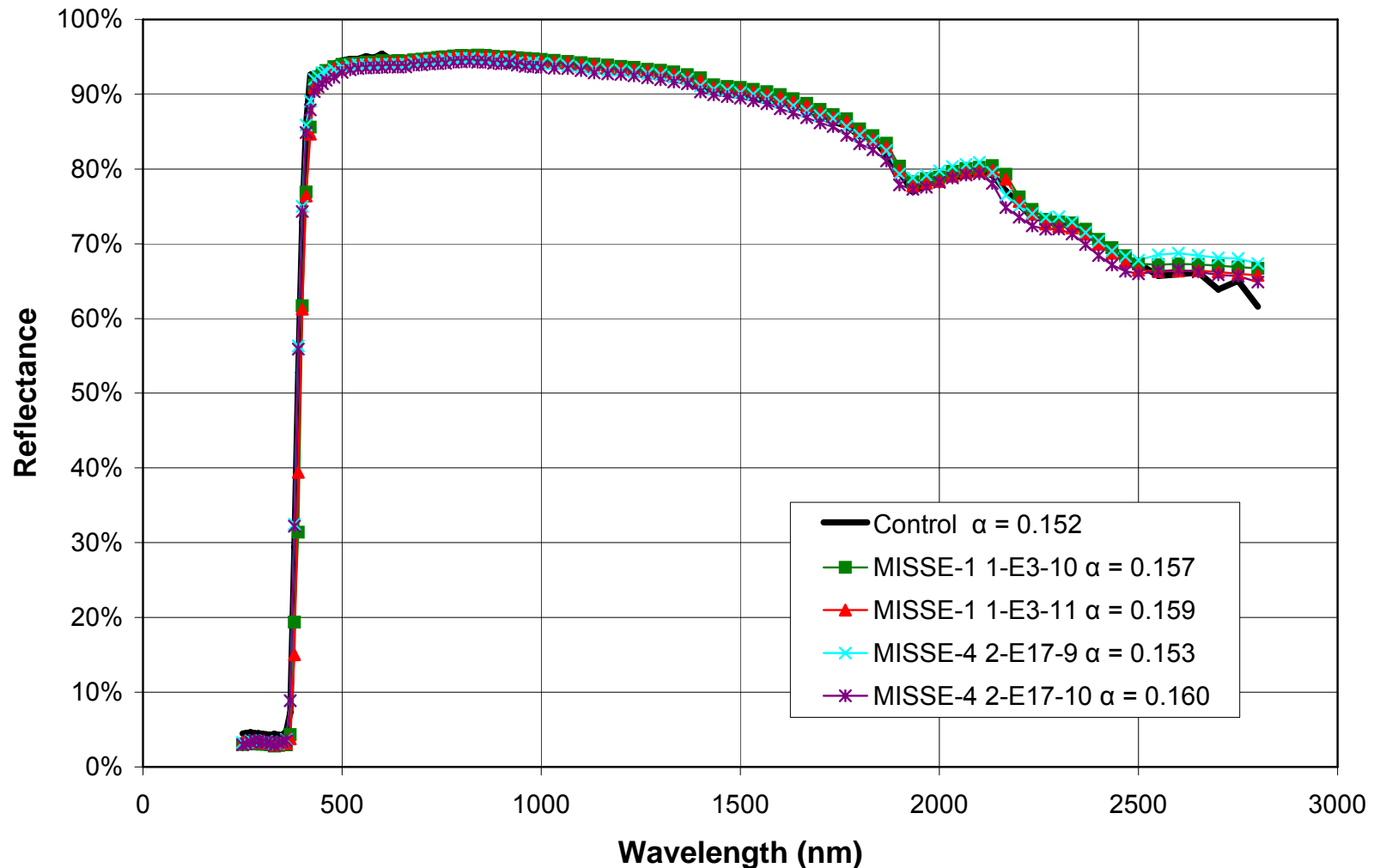
MISSE-3 & 4 AZ93



MISSE Thermal Control Materials
With Comparison to Previous Flight Experiments



Post-Flight MISSE AZ93 / MLP-300-AZ on Composite



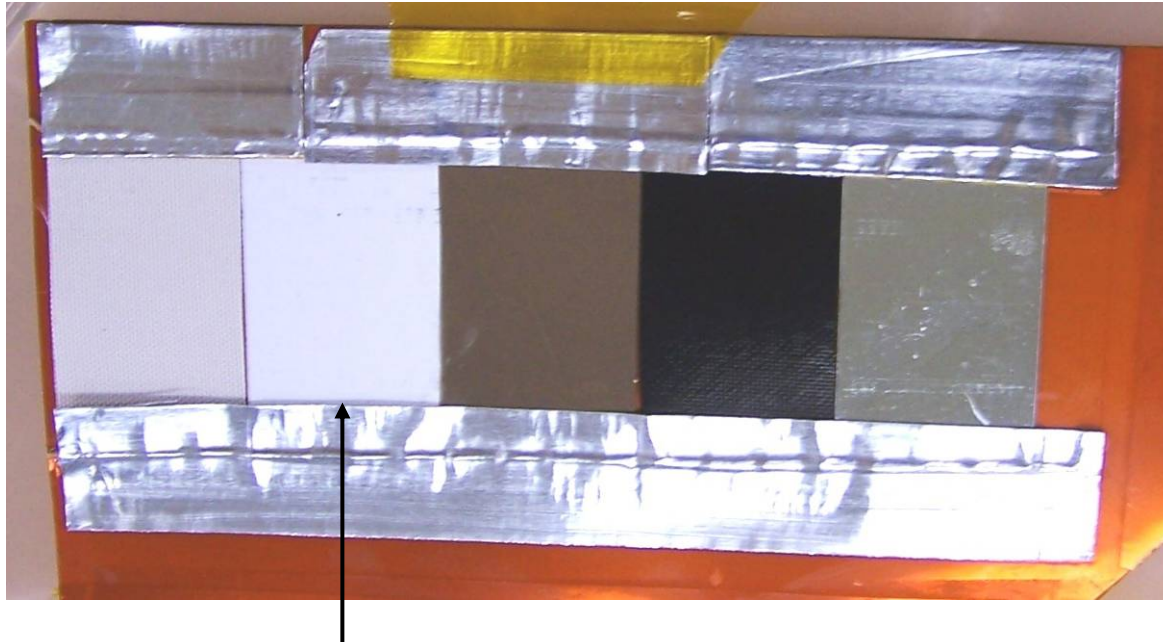
MISSE Thermal Control Materials With Comparison to Previous Flight Experiments



Environmental Exposure

- ~ 1.8×10^{20} atoms/cm² atomic oxygen (Kapton erosion)
- ~ 525 equivalent sun-hours UV
- >6,500 thermal cycles of + 40/- 40 °C

**MISSE Thermal Control Materials
With Comparison to Previous Flight Experiments**



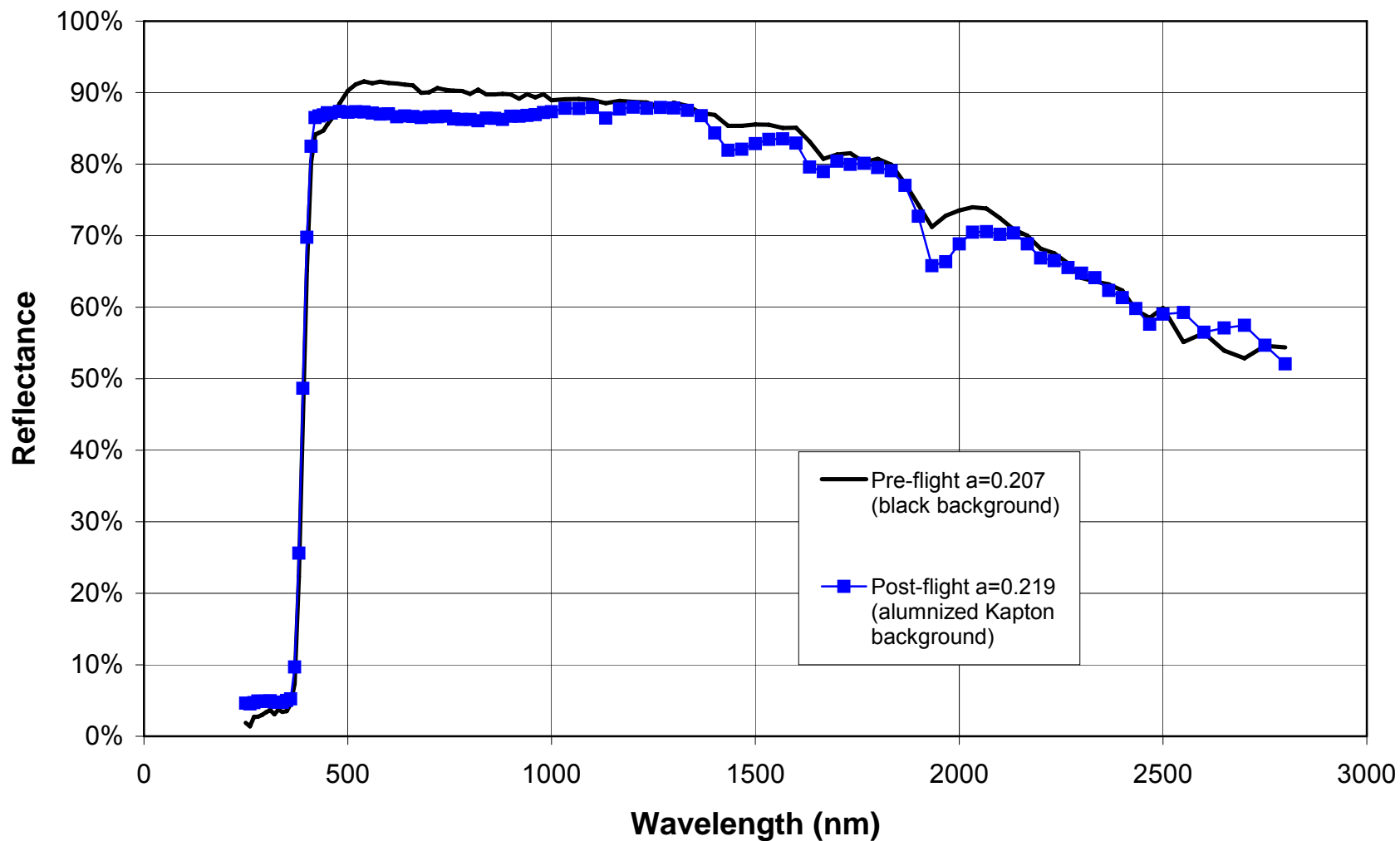
AZ93 on Kapton

- Thinner layer than aluminum substrate
- No indication of contamination at 400 nm knee

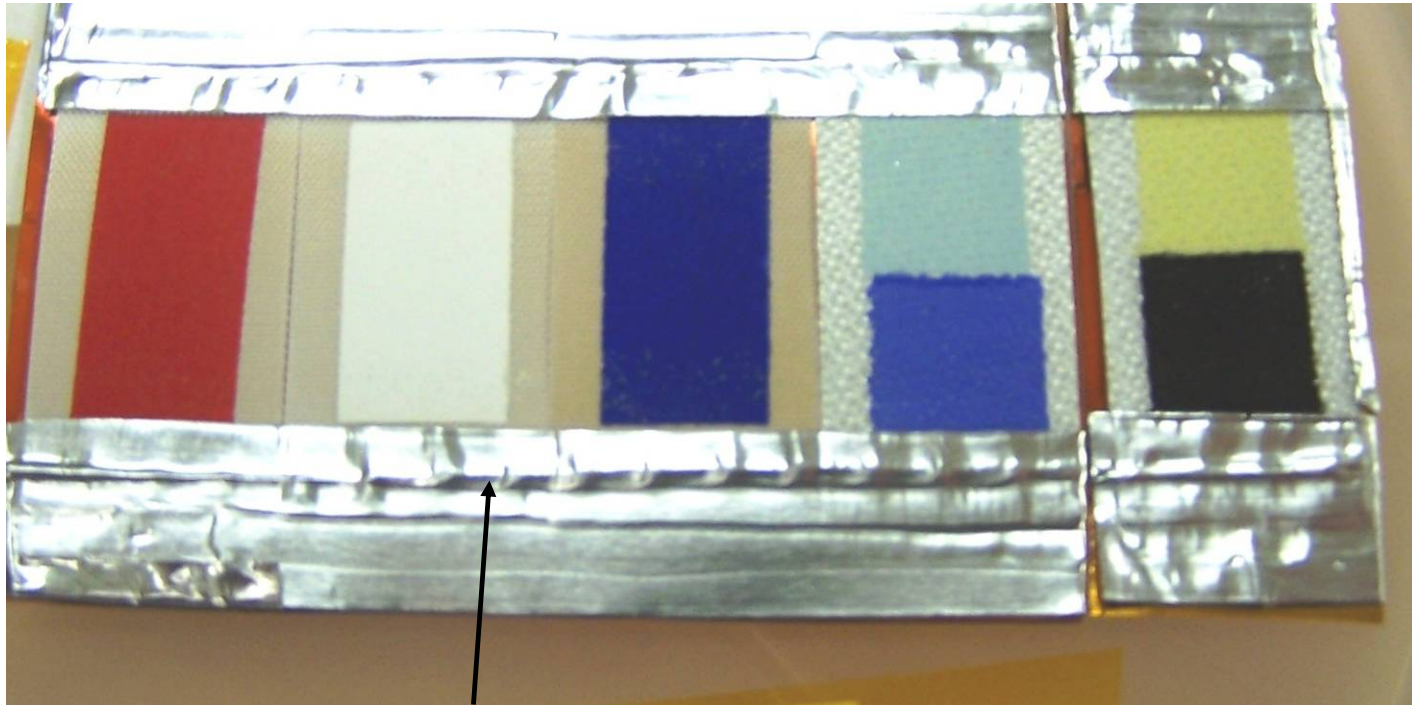
MISSE Thermal Control Materials
With Comparison to Previous Flight Experiments



MISSE-5 AZ93 on Kapton



**MISSE Thermal Control Materials
With Comparison to Previous Flight Experiments**



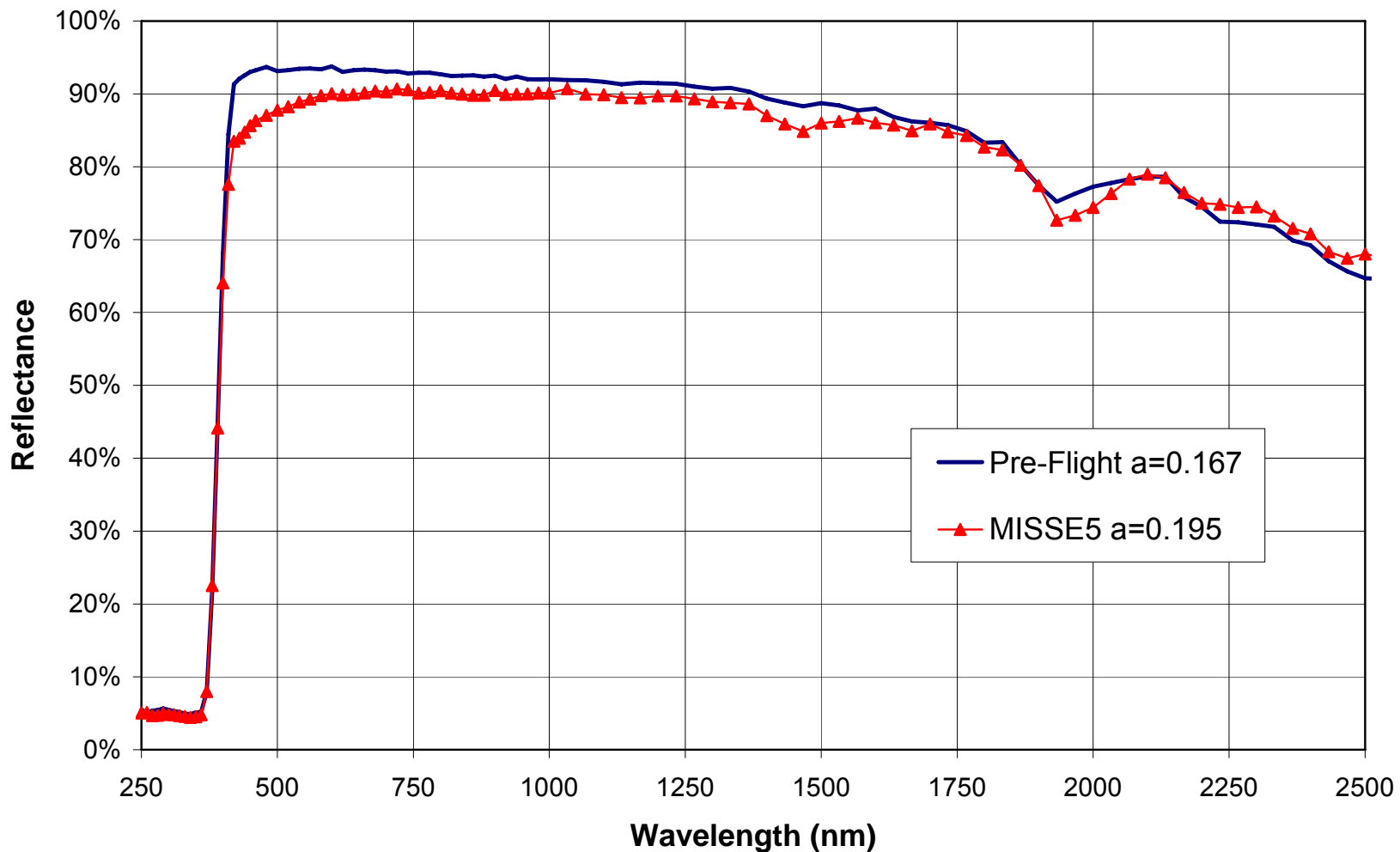
AZ93 on Beta Cloth looks white.

Change in reflectance spectra may indicate darkening of beta cloth underneath coating.

MISSE Thermal Control Materials
With Comparison to Previous Flight Experiments



MISSE-5 AZ93 on Beta Cloth
No Aluminization





Deft Coatings

Used on the Solid Rocket Booster

Proposed for use on Ares-I First Stage

Also considered for LCROSS

Lunar CRater Observation and Sensing Satellite

- 03-W-127A - current standard
- ELT - Extended Life Topcoat
- Zero VOC - Volatile Organic Compound

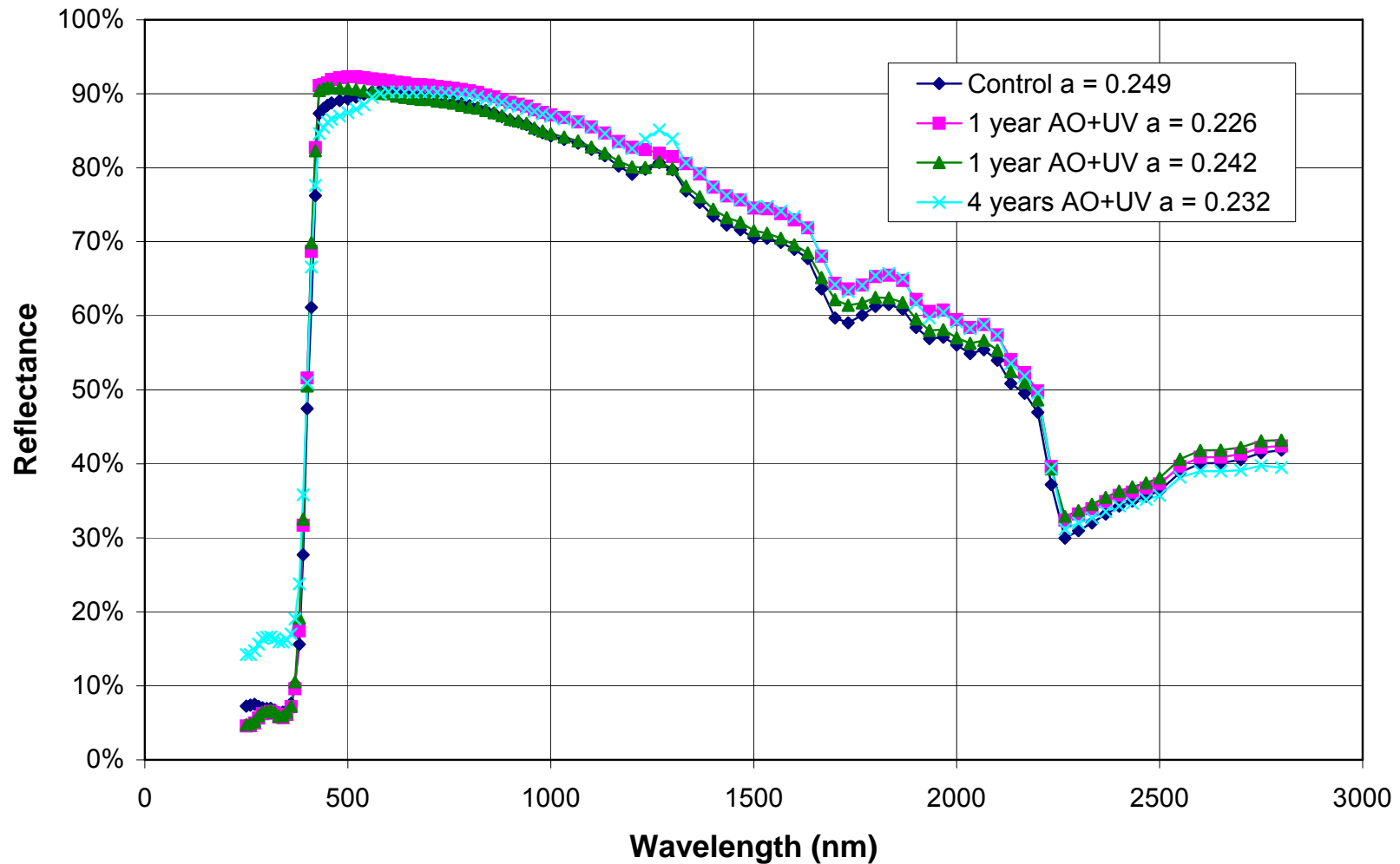
Solar absorptance (air mass zero) is converted to solar absorptance (air mass 1.5) for ground thermal analyses

On-going effort to reduce environmental impact

MISSE Thermal Control Materials
With Comparison to Previous Flight Experiments



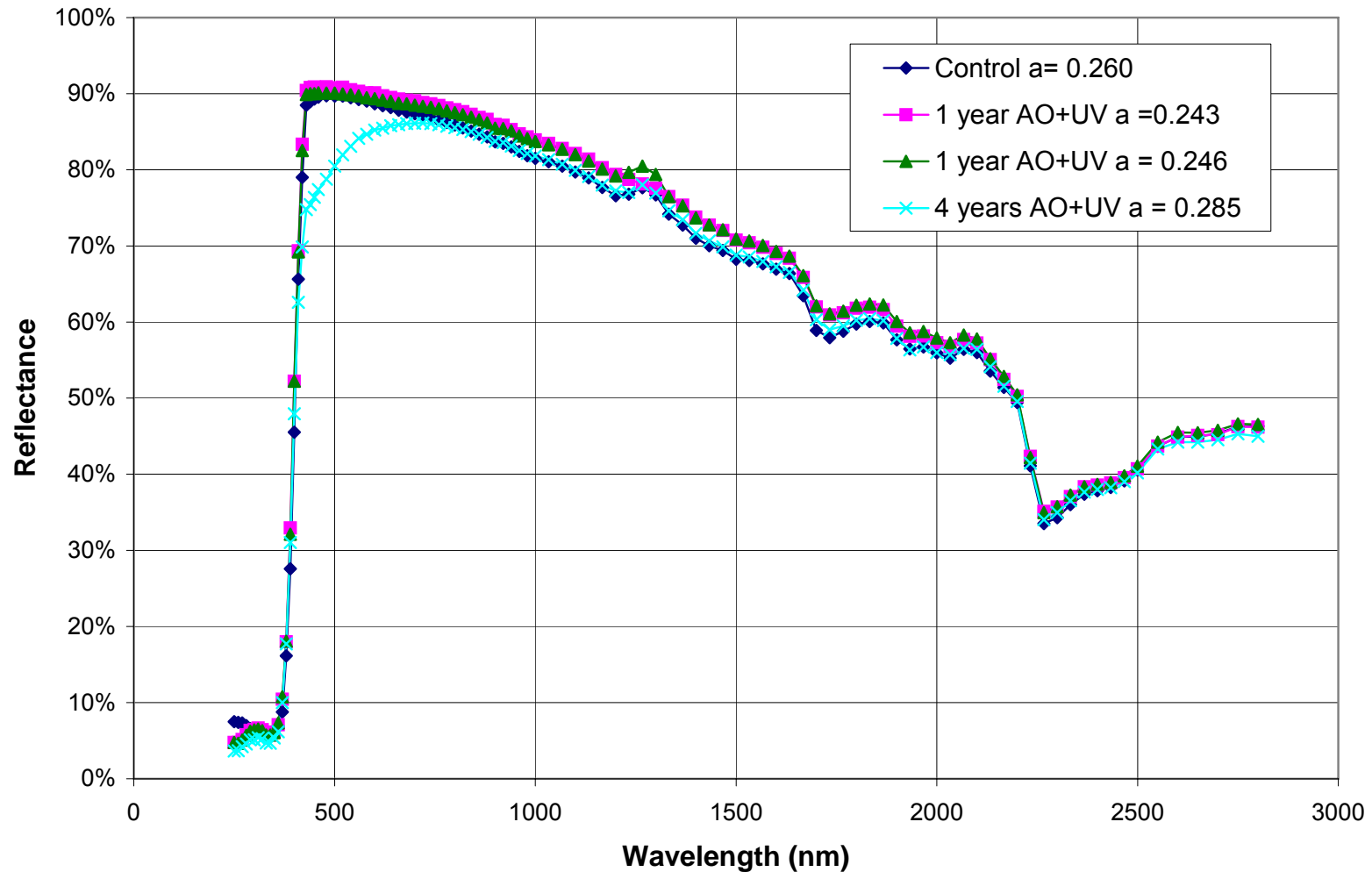
DEFT Topcoat 03-W-127A



MISSE Thermal Control Materials With Comparison to Previous Flight Experiments



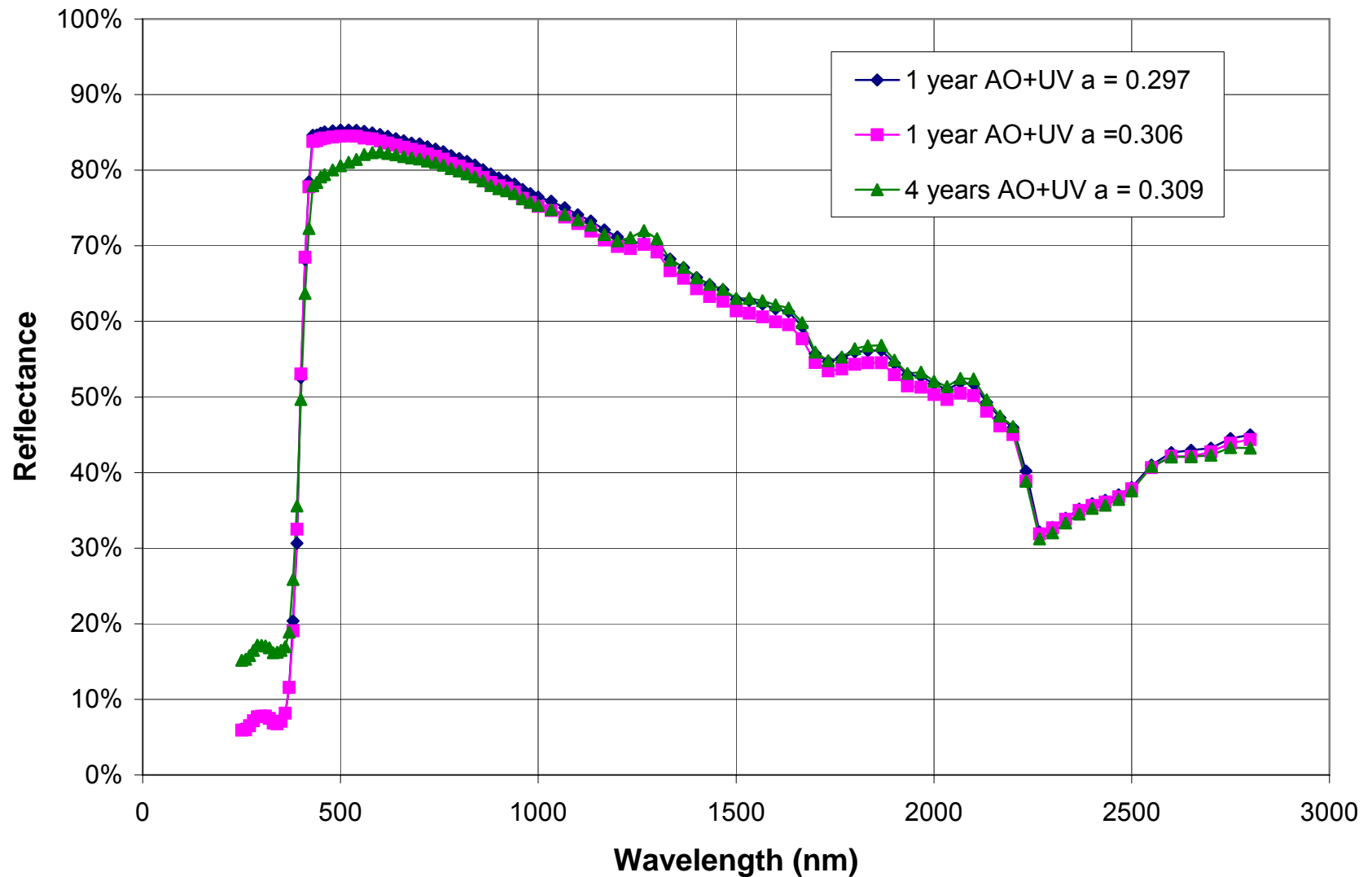
DEFT ELT 99-006



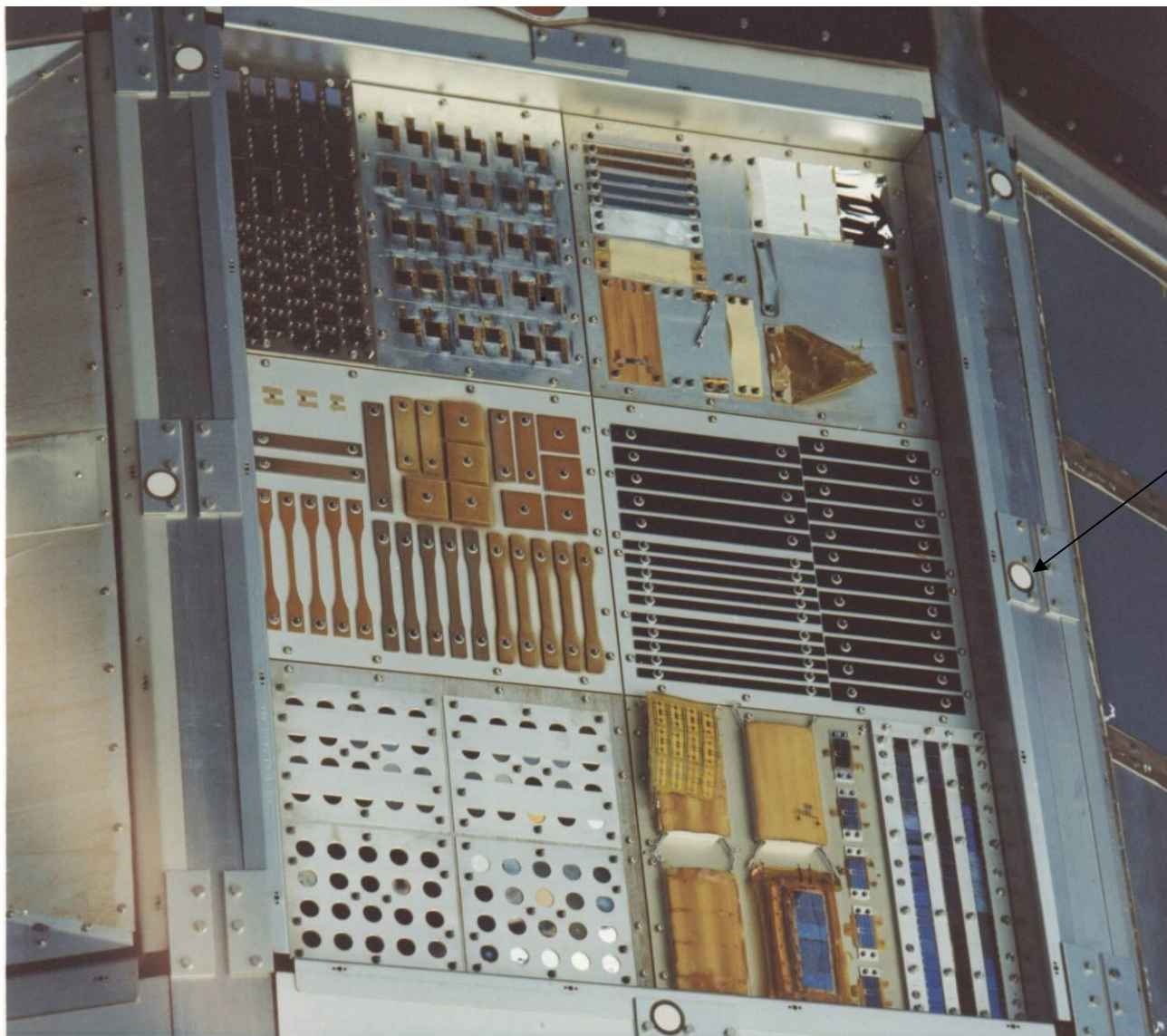
MISSE Thermal Control Materials
With Comparison to Previous Flight Experiments



DEFT Zero VOC

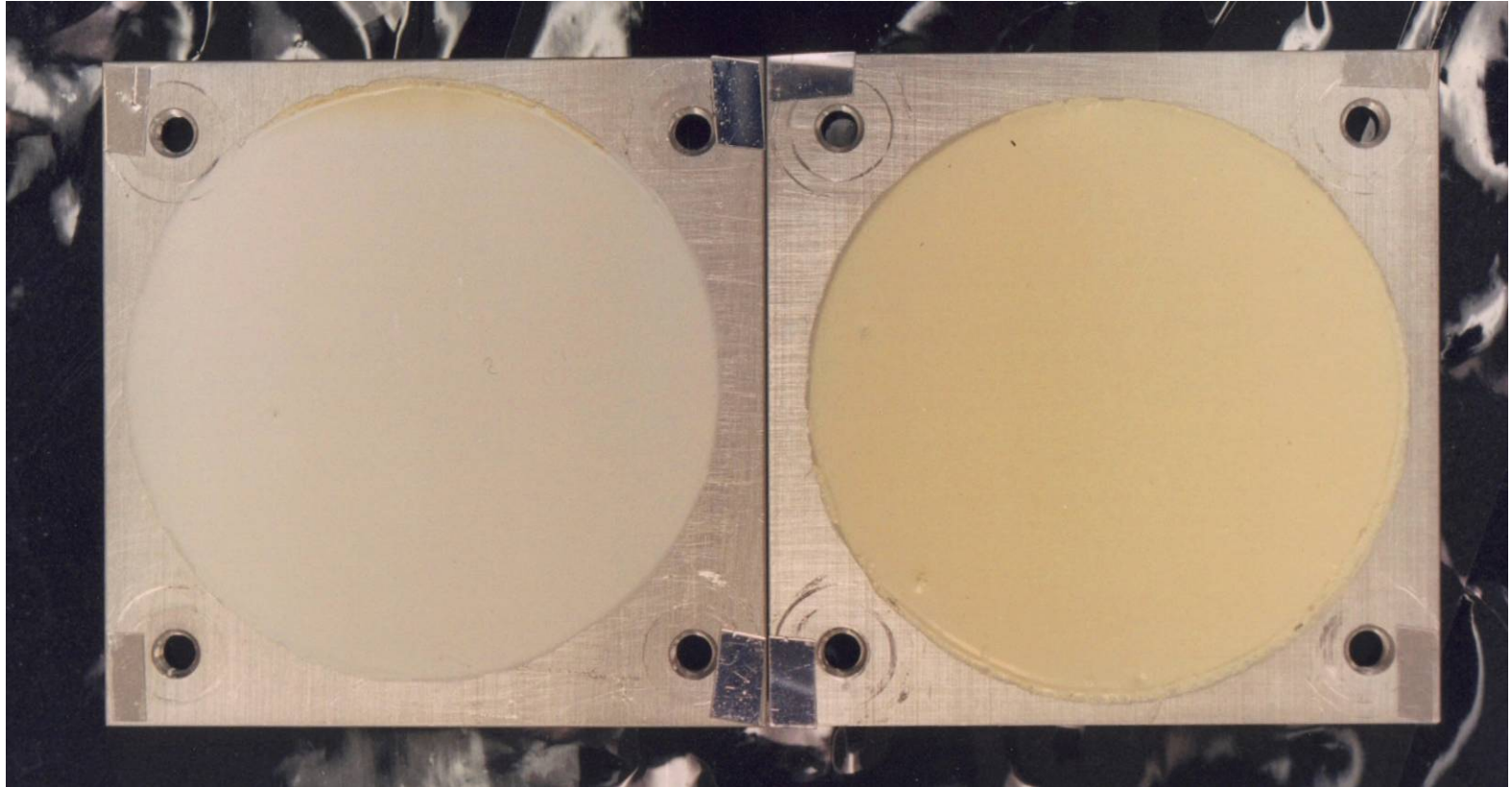


MISSE Thermal Control Materials With Comparison to Previous Flight Experiments



A-276 on
tray clamps

**MISSE Thermal Control Materials
With Comparison to Previous Flight Experiments**



A-276 from A0034 Experiment
Leading Edge Trailing Edge



Lord Chemical Aeroglaze A-276

Many samples flown on LDEF

BOL $\alpha = 0.23 \pm 0.03$ per MSFC-PROC-547

Leading edge $\alpha = 0.30 \pm 0.03$

Trailing edge α as high as 0.57

MISSE samples

Leafing aluminum added for charge dissipation

1%, 3%, 5%, 10%, 15% by volume

Long-term use in LEO not recommended

Polyurethane binder susceptible to AO erosion

OK for short missions, like flight support equipment

MISSE Thermal Control Materials
With Comparison to Previous Flight Experiments



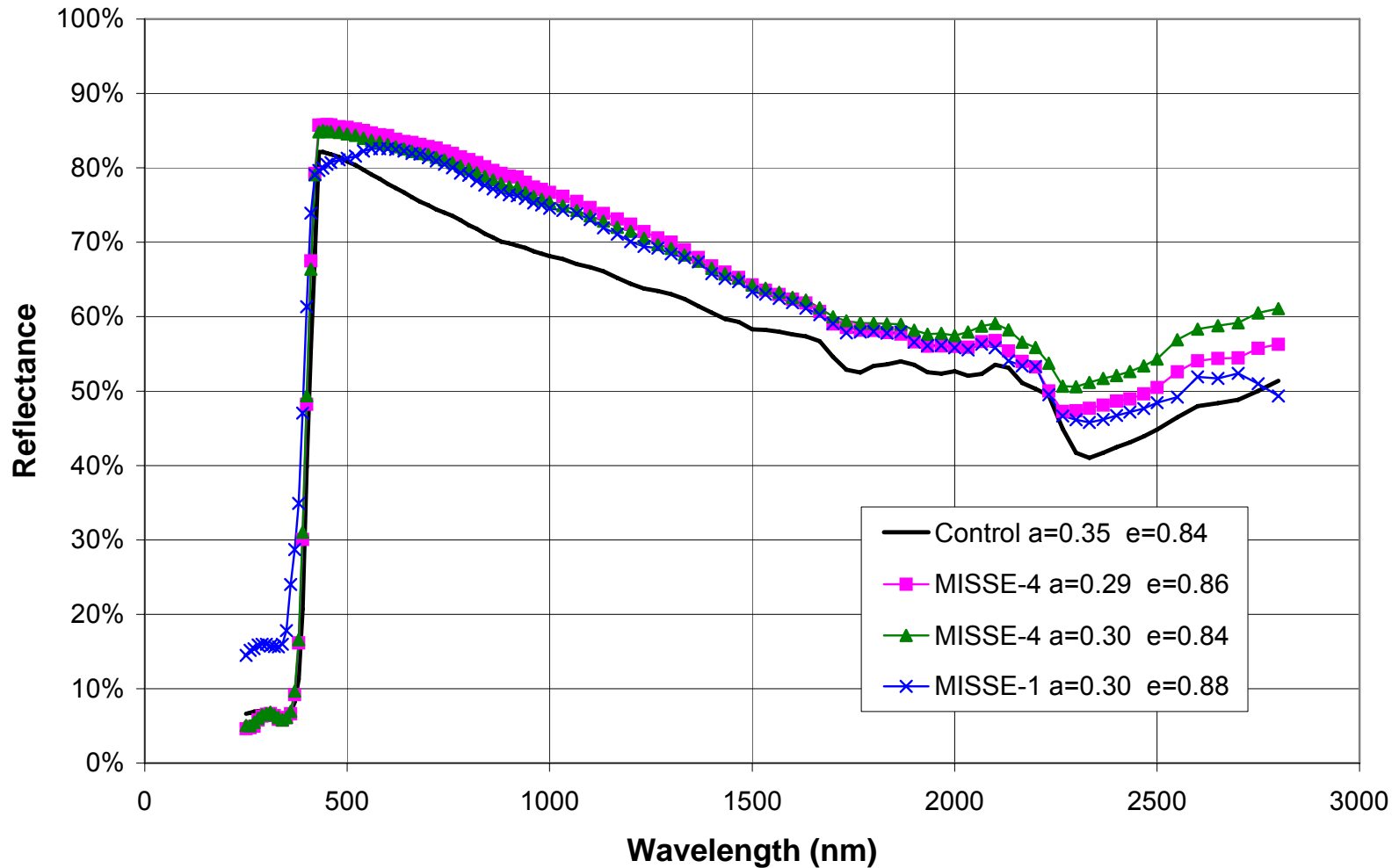
A-276 with Leafing Aluminum

Material	Exposure	AO (atoms/cm ²)	UV (ESH)	Solar Absorptance	Infrared Emittance
1%	Control	-	-	0.35	0.84
1%	MISSE-4	1.8 x 10 ²¹	~1,200	0.30	0.84
1%	MISSE-4	1.8 x 10 ²¹	~1,200	0.29	0.86
1%	MISSE-1	9.5 x 10 ²¹	5,700	0.30	0.87
5%	Control	-	-	0.40	0.79
5%	MISSE-4	1.8 x 10 ²¹	~1,200	0.31	0.78
5%	MISSE-1	9.5 x 10 ²¹	5,600	0.31	0.78
10%	Control	-	-	0.42	0.76
10%	MISSE-1	9.5 x 10 ²¹	5,600	0.32	0.74
10%	MISSE-2	1.7 x 10 ²⁰	5,900	0.33	0.72
15%	Control	-	-	0.42	0.76
15%	MISSE-4	1.8 x 10 ²¹	~1,200	0.30	0.69
15%	MISSE-2	1.7 x 10 ²⁰	5,900	0.38	0.71

MISSE Thermal Control Materials
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A-276 with 1% Leafing Aluminum





Conclusions

- ◆ Zinc oxide pigment with inorganic binder held up well with up to four years in LEO {AO+UV} environment.
- ◆ No evidence of significant contamination.
- ◆ Some yellowing of the Deft ELT coating.
- ◆ Some bleaching of the A-276 with leafing aluminum.